

One-Stop Hybrid Coronary Revascularization Versus Coronary Artery Bypass Grafting and Percutaneous Coronary Intervention for the Treatment of Multivessel Coronary Artery Disease

3-Year Follow-Up Results From a Single Institution

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Objectives	This study sought to compare midterm clinical outcomes of 1-stop hybrid coronary revascularization (HCR) with coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) for the treatment of multivessel coronary artery disease.
Background	One-stop HCR has emerged to be a feasible and attractive alternative to CABG and PCI in selected patients with multivessel coronary artery disease.
Methods	From June 2007 to December 2010, 141 consecutive patients underwent 1-stop HCR at Fuwai Hospital. Using propensity score methodology, these patients were matched with 2 separate groups of 141 patients who underwent isolated CABG or PCI during the same period. All patients were stratified by the EuroSCORE (European System for Cardiac Operative Risk Evaluation Score) and the SYNTAX (Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery) score. Cutoffs for EuroSCORE (low, ≤ 2 ; medium, >2 and <6 ; high, ≥ 6) and SYNTAX score (low, ≤ 24 ; medium, >24 and <30 ; high, ≥ 30) were identified by tertiles. Three groups' cumulative major adverse cardiac or cerebrovascular events (MACCE) rates in each risk tertile were compared.
Results	One-stop HCR incurred MACCE rate lower than that with PCI ($p < 0.001$), but similar to that with CABG ($p = 0.140$). After stratification by EuroSCORE or SYNTAX score, the cumulative MACCE rates were similar among the 3 groups in low and medium tertiles. But in the high EuroSCORE tertile, patients who underwent 1-stop HCR had a lower MACCE rate than did the groups that underwent CABG ($p = 0.030$) and PCI ($p = 0.006$). Meanwhile, patients with a high SYNTAX score who underwent 1-stop HCR had a MACCE rate lower than did those who underwent PCI ($p = 0.002$), but similar to that of those who underwent CABG ($p = 0.362$).
Conclusions	One-stop HCR provides favorable midterm outcomes for selected patients with multivessel coronary artery disease in each risk tertile. For patients with high EuroSCORE or SYNTAX score, it might provide a promising alternative to CABG and PCI. (J Am Coll Cardiol 2013;61:2525–33) © 2013 by the American College of Cardiology Foundation

Both coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) offer certain benefits for patients with multivessel coronary artery disease. The longevity of the left internal mammary artery (LIMA) to left anterior descending coronary artery (LAD) graft (10-year patency $>90\%$) contributes substantially to the survival

advantage of CABG (1–4). However, CABG is a relatively high-risk procedure and saphenous vein graft patency declines significantly with time: 10% to as many as 25% of grafts occlude within 1 year; an additional 1% to 2% occlude each year during the 1 to 5 years after surgery (3–6). On the other hand, although PCI, a much less invasive procedure as an

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Abbreviations and Acronyms

CABG	= coronary artery bypass graft
DES	= drug-eluting stent(s)
HCR	= hybrid coronary revascularization
LAD	= left anterior descending coronary artery
LIMA	= left internal mammary artery
MACCE	= major adverse cardiac or cerebrovascular event(s)
PCI	= percutaneous coronary intervention

alternative to CABG, has long been an attractive option, the need for subsequent repeat revascularization is still a big concern (7). These shortcomings provided room to develop a new combined revascularization procedure. Hybrid coronary revascularization (HCR) represents a minimally invasive alternative strategy that combines the durability and survival advantage of LIMA-LAD grafting with less invasive PCI to treat non-LAD lesions. Moreover, with the introduction of the hybrid operating suite, both surgical and percutaneous procedures

could be performed consecutively in the same setting. In initial experiences, 1-stop HCR has proven to be a safe and feasible option with acceptable clinical outcomes in selected patients with multivessel coronary artery disease (8–12). However, few studies are available on the outcomes of this new hybrid revascularization strategy versus CABG and PCI.

In this study, we compared midterm clinical outcomes after 3 procedures in a propensity-matched subset of patients at Fuwai Hospital. All patients in the 3 groups were stratified by the EuroSCORE (European System for Cardiac Operative Risk Evaluation score) and the SYNTAX (Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery) score, 2 typical score systems for clinical and angiographic variables (7,13–15), to identify which subgroup of patients got optimal outcomes from 1-stop HCR.

Methods

Patient selection. Inclusion criteria for 1-stop HCR were as follows: 1) unfavorable LAD for PCI (i.e., chronic total occlusion, excessive tortuosity, severely diffuse lesion), unprotected left main coronary artery disease, and non-LAD lesions were technically feasible for PCI with a drug-eluting stent (DES); and 2) limitations to traditional CABG, such as pre-existing organ dysfunction, heavily calcified proximal aorta, or lack of suitable graft conduits.

Exclusion criteria for 1-stop HCR included left subclavian artery and LIMA stenosis, buried intramyocardial LAD, need for a concomitant operation (e.g., valve repair or replacement), overt congestive heart failure, hemodynamic instability, and other conditions rendering PCI unsuitable (e.g., fresh thrombus, coronary vessel diameter <1.5 mm).

Since the first hybrid operation room was established at Fuwai Hospital in 2007, a hybrid Heart Team, composed of 2 experienced interventional cardiologists and 2 experienced cardiac surgeons, had been established in 1 cardiology ward. If the patient's data met with these inclusion criteria, the Heart Team would review the patient's medical condition

and coronary anatomy, and determine whether both LIMA-LAD grafting and PCI for non-LAD lesions could be feasible and reasonable. The ultimate decision regarding revascularization options was reached only after careful discussion between the Heart Team and the patient.

From June 2007 to December 2010, 141 consecutive patients underwent 1-stop HCR with LIMA-LAD grafting and DES to non-LAD lesions at Fuwai Hospital. During the same period, 5,797 patients underwent isolated CABG with LIMA-LAD grafting and saphenous grafts to non-LAD lesions through median sternotomy, and 4,254 patients underwent PCI with DES both for LAD and non-LAD lesions. Using propensity score matching, 2 separate groups of 141 patients were selected from these 2 cohorts as controls (Fig. 1). Matching criteria included demographics, comorbidities, and coronary anatomy variables known to be risk factors for revascularization. This study had been approved by the institutional review board of Fuwai Hospital.

Surgical procedure. ONE-STOP HCR. The procedure and antiplatelet strategy were performed as we described before (12,16). Briefly, LIMA conduit was harvested as a pedicle under direct vision through a lower partial ministernotomy, and the distal anastomosis of in situ LIMA-LAD grafting was completed with the aid of a stabilizing device (Pilling Weck Surgical Co., Research Triangle Park, North Carolina). After closure of the thorax, angiography was immediately performed to confirm patency of the LIMA-LAD graft and then PCI was performed on non-LAD lesions through the femoral artery. Guidewire and stent selection were left to the discretion of the interventionist. Aspirin 100 mg/day was continued perioperatively, while clopidogrel was discontinued at least 7 days before the operation. A loading dose of clopidogrel 300 mg was administered via a nasogastric tube after confirmation of LIMA-LAD graft patency. Unfractionated heparin was then administered again to obtain an activated clotting time >250 s. Aspirin dosage was 300 mg/day for 1 month and 100 mg/day for lifetime, while clopidogrel was administered as a maintenance dose at 75 mg/day for 12 months. Glycoprotein IIb/IIIa antagonist was not used perioperatively.

CABG. All patients received general anesthesia and tracheal intubation. The choice of off-pump or on-pump coronary artery bypass for a particular patient was made at the discretion of qualified responsible surgeons. For the off-pump procedure, several standard cardiac positioning techniques and coronary artery stabilizers were adopted (17). For the on-pump procedure, standard cardiopulmonary bypass techniques were used that incorporated cold antegrade and retrograde blood cardioplegia and moderate systemic hypothermia. Apart from differences in surgical procedures, all other aspects of in-hospital management were done similarly according to standard protocols in this institute.

PCI. For multivessel coronary artery disease, PCI was performed according to current practice guidelines. Insertion of

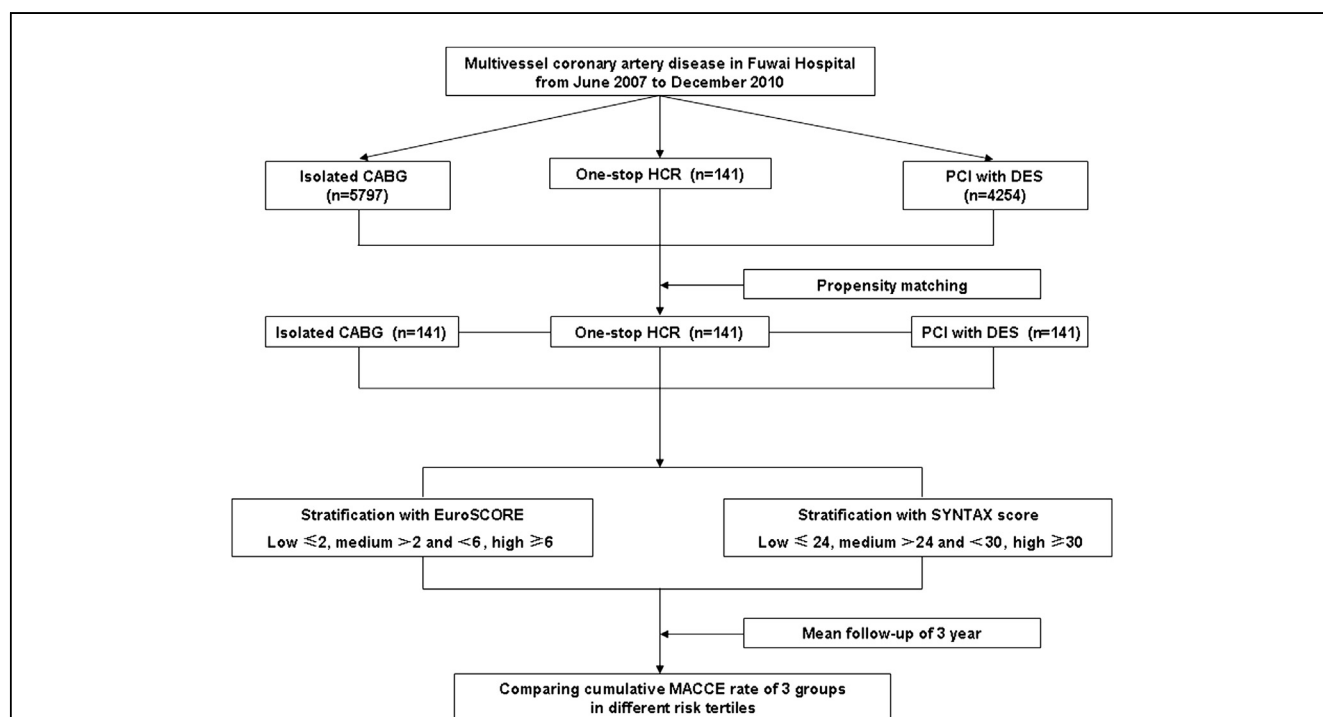


Figure 1 Flowchart of the Study Design

CABG = coronary artery bypass grafting; DES = drug-eluting stent(s); EuroSCORE = European System for Cardiac Operative Risk Evaluation score; HCR = hybrid coronary revascularization; MACCE = major adverse cardiac or cerebrovascular event(s); PCI = percutaneous coronary intervention; SYNTAX = Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery.

DES was performed with an attempt to fully cover the diseased segment and to ensure complete stent apposition. The choice of the specific type of DES was left to the interventionist's discretion. All patients undergoing PCI were prescribed aspirin plus clopidogrel (loading dose, 300 mg) before or during the coronary intervention. After the procedure, all patients were on continuous aspirin therapy (300 mg/day for 1 month and then switching to 100 mg/day for lifetime) and clopidogrel 75 mg/day was prescribed for 6 to 12 months following implantation of DES.

Calculation of scores and stratification. Demographic and clinical data were retrospectively collected on a dedicated database. EuroSCORE was calculated on the basis of the original methodology (13). Coronary angiograms were analyzed by an independent angiographic core lab (CCRF, Beijing, China) by experienced technicians. Diagnostic angiograms were scored, according to the SYNTAX score algorithm (15). EuroSCORE cutoffs (low, ≤ 2 ; medium, > 2 and < 6 ; high, ≥ 6) were identified by consensus. Subgroups of the SYNTAX score were identified by tertiles (low, ≤ 24 ; medium, > 24 and < 30 ; high, ≥ 30).

Study endpoints and follow-up. The primary endpoint during follow-up was the incidence of major adverse cardiac or cerebrovascular events (MACCE), a composite of death, myocardial infarction (classical symptoms, electrocardiogram

and serum cardiac biomarkers changes), neurologic event (stroke or transient ischemic attack), and target lesion or vessel repeat revascularization.

As part of institutional standard procedures, all surgical and interventional patients were required to return for an outpatient follow-up visit at 6 months after discharged from the hospital and then once every year. Holter, chest X-ray, and ultrasonic cardiography were set as routine programs. Myocardial perfusion imaging was recommended for patients without ischemic symptoms. Angiography would be performed if noninvasive diagnostic tests indicated the sign of ischemia. Both myocardial perfusion and angiography were strongly recommended for patients with the recurrence of ischemic symptoms. Hospital databases were checked annually to identify and review any routine follow-up information. In addition, all participants in the present study were contacted by telephone or mail again by the research staff using standard procedures and forms.

Statistics. A multivariate logistic regression model was used to develop a propensity score for each patient. All prespecified covariates were listed in Table 1. Nearest-neighbor propensity score matching was subsequently used to match patients in the 1-stop HCR group with those in the CABG and PCI cohorts. Continuous variables were

Table 1 Demographic and Clinical Baseline Characteristics

	Hybrid (n = 141)	CABG (n = 141)	PCI (n = 141)	p Value
Age, yrs	62.0 ± 9.9	62.4 ± 7.8	61.7 ± 10.3	0.977
Male	88.7%	90.1%	87.23%	0.754
BMI, kg/m ²	25.8 ± 2.8	25.4 ± 2.8	25.7 ± 2.7	0.463
Smoker	55.3%	66.0%	24.8%	<0.001
Diabetes mellitus	26.2%	18.4%	19.9%	0.236
Hypercholesterolemia	53.2%	55.3%	48.9%	0.550
Hypertension	64.5%	65.2%	59.6%	0.561
Renal dysfunction	2.8%	3.5%	5.0%	0.635
Previous cerebrovascular accident	10.6%	12.1%	19.1%	0.087
COPD	7.1%	8.5%	7.8%	0.906
Peripheral arterial disease	24.1%	25.5%	29.1%	0.621
Previous MI	27.7%	31.2%	27.7%	0.750
LVEF, %	62.7 ± 7.1	62.6 ± 8.0	61.2 ± 9.3	0.508
Previous PCI	9.2%	7.8%	14.2%	0.183
SYNTAX score	27.6 ± 7.9	28.2 ± 9.4	26.0 ± 8.2	0.060
EuroSCORE	3.1 ± 2.3	3.3 ± 2.3	3.5 ± 2.6	0.655
LM	19.90%	22.7%	15.6%	0.317
LAD	100%	100%	100%	1.000
LCX	65.2%	75.9%	72.3%	0.133
RCA	75.2%	83.7%	77.3%	0.192

Values are mean ± SD or %.

BMI = body mass index; COPD = chronic obstructive pulmonary disease; EuroSCORE = European System for Cardiac Operative Risk Evaluation score; LAD = left anterior descending coronary artery; LCX = left circumflex artery; LM = left main coronary artery disease; LVEF = left ventricular ejection fraction; MI = myocardial infarction; PCI = percutaneous coronary intervention; RCA = right coronary artery; SYNTAX = Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery.

expressed as mean ± SD, and categorical variables as frequencies and percentages. Categorical variables were compared using the chi-square statistic between groups. If continuous variables were normally distributed and variance was homogeneous, then they would be analyzed by 1-way analysis of variance. Otherwise, they would be analyzed by Kruskal-Wallis test. Kaplan-Meier methodology was used to compare cumulative MACCE rates between groups. A p value <0.05 was considered statistically significant. All statistical analysis was performed using the SPSS software package for Windows version 17.0 (SPSS Inc., Chicago, Illinois).

Results

Patient characteristics. After propensity score matching, baseline characteristics were similar in the 3 groups (Table 1). In the hybrid group, all patients received a LIMA-LAD graft and PCI with DES for non-LAD lesions, the mean number of stents implanted in a patient was 1.9, and the mean total length of the stents was 32.6 ± 15.1 mm (Table 2).

In the CABG group, 29 patients (20.6%) underwent off-pump surgery. All patients received a LIMA-LAD graft. Additionally, the CABG group received 289 saphenous vein grafts in non-LAD targets. The mean number of grafts was 3.0 (Table 3).

In the PCI group, the mean number of stents implanted in a patient was 2.7 (1.5 for non-LAD and 1.2 for LAD). The mean total length of the stents was 62.8 mm (32.5 mm

for non-LAD and 30.3 mm for LAD) (Table 4). Considering the complexity of coronary anatomy, 6 patients underwent staged procedures. The types of stents in the hybrid and PCI groups included the Cypher sirolimus-eluting stents (Cordis, Johnson & Johnson, Warren, New Jersey, Bridgewater, New Jersey), Taxus paclitaxel-eluting stents (Boston Scientific, Natick, Massachusetts), and Endeavor and Resolute zotarolimus-eluting stents (Medtronic, Minneapolis, Minnesota).

Midterm outcomes. By March 2012, follow-up information and hospital records review were 100% complete. At a mean follow-up of 3 years, actuarial survival rates in

Table 2 Procedural Characteristics of Patients in the Hybrid Group

Bypassed LIMA-LAD	141/141 (100%)
Stented patients	141/141 (100%)
Stented lesion	213
LM	16
Diagonal artery	14
LCX	69
RCA	114
Number of stents	271
Number of sirolimus-eluting stents	210
Number of paclitaxel-eluting stents	8
Number of Endeavor zotarolimus-eluting stents	12
Number of Resolute zotarolimus-eluting stents	41
Total stent length per patient, mm	32.6 ± 15.1

Values are n/N (%), n, or mean ± SD.

LIMA = left internal mammary artery; other abbreviations as in Table 1.

Table 3 Procedural Characteristics for Patients in CABG Group

Bypassed LIMA-LAD	141/141 (100%)
Saphenous vein	289
DA	56
LCX	15
OM	78
RCA	31
PDA	72
LVB	37
Number of distal anastomoses	3.0 ± 0.7

Values are n/N (%), n, or mean ± SD.

DA = diagonal artery; LVB = left ventricular branch; OM = obtuse marginal; PDA = posterior descending artery; other abbreviations as in Table 1.

the hybrid, CABG, and PCI groups were 99.3%, 97.2%, and 96.5%, respectively (log-rank $p = 0.344$). Six patients in the hybrid group, 3 patients in the CABG group, and 18 patients in the PCI group underwent repeat revascularization (Table 5).

Compared with the hybrid group, repeat revascularization in the PCI group was mainly concentrated in the LAD (2 vs. 10; $p = 0.029$), and PCI with DES for non-LAD offered a similar repeat revascularization rate in the hybrid and PCI groups (4 vs. 8; $p = 0.307$) (Table 6). The cumulative MACCE rate in the hybrid group (6.4%) was significantly lower than that in the PCI group (22.7%; $p < 0.001$), but similar to that in the CABG group (13.5%; $p = 0.140$) (Fig. 2). Overall, 61 patients (43.3%) in the hybrid group, 54 patients (38.3%) in the CABG group, and 63 patients (44.7%) in the PCI group underwent coronary angiography during follow-up.

Stratification by EuroSCORE. In the low and medium EuroSCORE tertiles, the MACCE rate in the hybrid group did not differ significantly with those in the CABG ($p = 0.959$ and $p = 0.914$, respectively) and PCI groups ($p = 0.352$ and $p = 0.172$, respectively). But in the high EuroSCORE tertile, the MACCE rate in the hybrid group was significantly lower than in the CABG ($p = 0.030$) and PCI groups ($p = 0.006$) (Table 7, Fig. 3).

Table 4 Procedural Characteristics of Patients in the PCI Group

Stented patients	141/141 (100%)
Stented lesion	342
LM	13
LAD	152
LCX	81
RCA	96
Number of stents	383
Number of sirolimus-eluting stents	231
Number of paclitaxel-eluting stents	5
Number of Endeavor zotarolimus-eluting stents	42
Number of Resolute zotarolimus-eluting stents	105
Total stent length per patient, mm	62.8 ± 29.1

Values are n/N (%), n, or mean ± SD.

Abbreviations as in Table 1.

Table 5 MACCE in the Hybrid, CABG, and PCI Groups

	Hybrid	CABG	PCI	p Value
Death	1	4	5	0.344
Myocardial infarction	0	3	6	0.062
Neurologic event	2	9	3	0.083
Repeat revascularization	6	3	18	<0.001
Any MACCE	9	19	32	0.003
Follow-up time, mean, yrs	2.9	3.2	3.0	

Values are numbers of events unless otherwise noted. n = 141 per group.

MACCE = major adverse cardiac or cerebrovascular event(s); other abbreviations as in Table 1.

Stratification by SYNTAX score. In the low and medium SYNTAX score tertiles, the MACCE rate in the hybrid group was not statistically different from those in the CABG ($p = 0.703$ and $p = 0.254$, respectively) and PCI groups ($p = 0.224$ and $p = 0.114$, respectively). Patients with a high SYNTAX score who underwent 1-stop HCR had a lower MACCE rate than that in the PCI group ($p = 0.002$), but similar to that in the CABG group ($p = 0.362$) (Table 8, Fig. 4).

Discussion

To our knowledge, this is by far the largest series of 1-stop HCR with the longest follow-up. The concept of HCR, first introduced by Angelini and colleagues in 1996 (18), is based on combining the excellent long-term patency of the LIMA-LAD graft by surgical procedure and minimal invasiveness of interventional procedures to achieve complete revascularization. Compared with the staged procedures, 1-stop HCR eliminated logistic concerns about the timing or sequencing of separate procedures and minimized the inconvenience of transferring patients and exposure to anesthesia. Especially when PCI complication or failure occurs, CABG can be performed immediately. And in the setting of coronary artery disease, both clinical variables and angiographic information are important in defining the risk of patients undergoing revascularization (15,19,20). Therefore we chose typical clinical and angiographic scoring systems, EuroSCORE and SYNTAX score, to stratify patients undergoing

Table 6 The Location of the Repeat Revascularization Performed in Hybrid, CABG, and PCI Groups

	Hybrid	PCI	CABG
LAD	2	10	2
Target lesion		6	
Nontarget lesion		4	
Non-LAD	4	8	1
Target lesion	1	1	
Nontarget lesion	3	7	

n = 141 per group. In the hybrid group, 1 patient each underwent repeat revascularization for LIMA graft occlusion and LAD de novo lesion. In the CABG group, 2 patients underwent repeat revascularization for LIMA graft occlusion and 1 patient for saphenous vein grafts occlusion.

Abbreviations as in Tables 1 and 2.

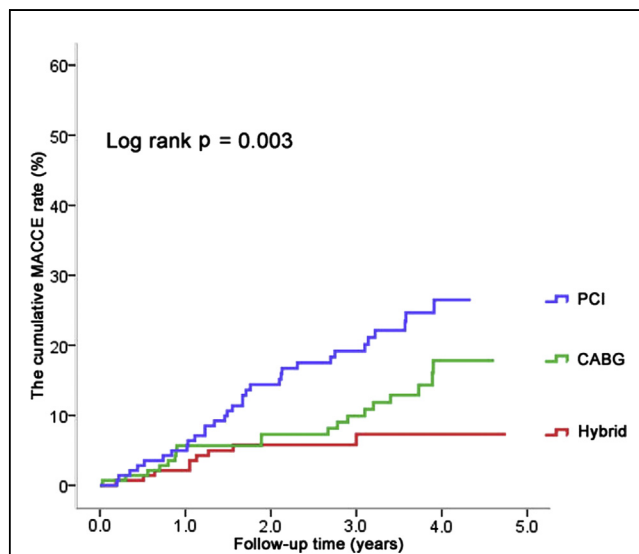


Figure 2 The Cumulative MACCE Rate in Hybrid, CABG, and PCI Groups

The cumulative MACCE rate in the hybrid group (6.4%) was significantly lower than that in the PCI group (22.7%; $p < 0.001$), but similar to that in the CABG group (13.5%; $p = 0.140$). Abbreviations as in Figure 1.

revascularization into 3 different risk levels; then midterm outcomes in each subgroup were compared between 1-stop HCR and conventional revascularization strategies.

Hybrid versus CABG. Compared to CABG, the advantages of 1-stop HCR lie in the following. First, LIMA-LAD graft quality was further confirmed by instant angiography and any deficiency could be corrected immediately. Combining the tools of the catheterization laboratory and operating room greatly enhanced the options available to

surgeons and changed surgeons' behavior by providing instant feedback on issues that were difficult to evaluate with the naked eye (21–24). In hybrid group, 4 major defects were found in LIMA-LAD grafts after intraoperative angiography, 2 in the LIMA conduit and 2 at the distal anastomosis. All 4 of the defects were surgically corrected by immediate reoperation. Zhao et al. (24) also reported that 7% of angiographic defects in LIMA-LAD grafts were identified after intraoperative angiography, which may have otherwise been missed.

Second is the avoidance of aortic manipulation, 1 of the unique characteristics of the hybrid technique. Aortic clamping, a predictor of postoperative cerebral infarction, is still required during both on-pump and off-pump bypass surgeries (25). Avoiding aortic manipulation can provide superior neurologic outcomes irrespective of aortic screening strategy or severity of atherosclerotic disease (26,27). In the present study, the incidence of neurologic events in the hybrid and CABG groups showed no statistical difference ($p = 0.056$) (Fig. 5), but the observed trend and the numerical difference was quite remarkable (1.4% vs. 6.4%).

Third is the minimal invasiveness. The lesser invasiveness of HCR could offer superior perioperative outcomes, including reduced lengths of intubation and ICU stay, and less transfusion than CABG (9,12). Meanwhile, through minimally invasive CABG for LAD and PCI for non-LAD lesions, HCR provided a feasible option to some clinically high-risk patients who were unable to tolerate median sternotomy, extracorporeal circulation, or heart rotation during off-pump CABG. Some other retrospective series also found that HCR was safe and reliable in select clinically high-risk patients, with low mortality and morbidity rates (28–30). Furthermore, compared with bare-metal stents, DESs significantly reduced the restenosis rate, which was similar to or lower than the failure rate of saphenous grafts (3–6,31,32). Therefore, combining the LIMA-LAD graft with DES on the remaining lesions appeared to be a valid alternative to conventional CABG in select patients. Our midterm results showed that 1-stop HCR also had a relatively low revascularization rate that was similar to that in the CABG group (4.3% vs. 2.1%; $p = 0.244$). Longer follow-up time and larger sample sizes are necessary to validate this finding.

Hybrid versus PCI. Compared with PCI, the main difference of 1-stop HCR lies in the LIMA-LAD graft. The primary objective of HCR in the present study was to cover patients with LAD chronic total occlusion, excessive tortuosity, severely diffuse lesion, and unprotected left main artery. It has been confirmed that the complexity of the coronary lesion directly affects the outcomes of PCI, especially the need for repeat revascularization, while the success of grafting is primarily related to the quality of the distal targets, not the lesions themselves (7). As shown in Table 6, repeat revascularization in the PCI group was mainly concentrated in the LAD, while PCI with DES for non-

Table 7 MACCE in Hybrid, CABG, and PCI Groups From Low to High EuroSCORE Tertile

	Hybrid	CABG	PCI	p Value
Low	n = 60	n = 58	n = 53	
Death	0	0	0	
Myocardial infarction	0	0	2	0.143
Neurologic event	1	2	0	0.389
Repeat revascularization	1	0	3	0.167
Any MACCE	2	2	5	0.336
Medium	n = 52	n = 50	n = 53	
Death	1	2	1	0.829
Myocardial infarction	0	0	2	0.154
Neurologic event	0	1	1	0.641
Repeat revascularization	4	2	7	0.259
Any MACCE	5	5	11	0.206
High	n = 29	n = 33	n = 35	
Death	0	2	4	0.214
Myocardial infarction	0	3	2	0.290
Neurologic event	1	6	2	0.163
Repeat revascularization	1	1	8	0.015
Any MACCE	2	12	16	0.030

Abbreviations as in Tables 1 and 5.

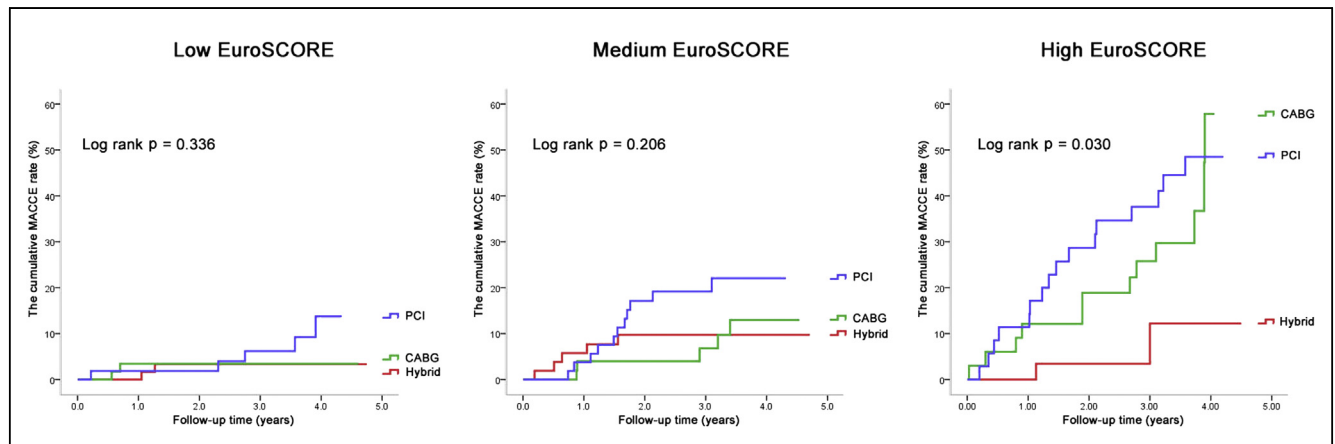


Figure 3 The Cumulative MACCE Rate in the Hybrid, CABG, and PCI Groups From Low to High EuroSCORE Tertile

In the low and medium European System for Cardiac Operative Risk Evaluation score (EuroSCORE) tertiles, the 1-stop HCR group had a MACCE rate similar to those in the CABG ($p = 0.959$ and $p = 0.914$, respectively) and PCI groups ($p = 0.352$ and $p = 0.172$, respectively). In the high EuroSCORE tertile, the MACCE rate in the hybrid group was significantly lower than those in the CABG ($p = 0.030$) and PCI groups ($p = 0.006$). Abbreviations as in Figure 1.

LAD offered relatively low and similar repeat revascularization rates in both the hybrid and PCI groups. Therefore, for multivessel coronary disease with complex LAD lesions, grafting LAD with LIMA combined PCI for the remaining lesions might be a potentially ideal alternative to conventional revascularization strategies. In addition, the challenging percutaneous procedure of unprotected left main coronary artery disease could be converted to a more straightforward one, with myocardial protection provided by patent LIMA-LAD graft (33,34).

Meanwhile, the minimal invasiveness of PCI makes it a favorable revascularization strategy for patients with clinically high-risk characteristics that predict an increased rate

of adverse surgical outcomes. Considering that the superior longevity of LIMA-LAD graft had a significantly positive impact on long-term survival, especially in certain patients with clinical risk factors (e.g., advanced age, diabetes, renal insufficiency, and impaired ventricular function) (35–37), the hybrid revascularization procedure, which combined minimally invasive CABG for LAD and PCI for non-LAD lesions, may provide a safe and feasible alternative to PCI for these patients. In the present study, both PCI and 1-stop HCR offered relatively low cumulative MACCE rates in patients with a high EuroSCORE.

Patient selection and heart team approach. As suggested in the 2011 American College of Cardiology Foundation/American Heart Association Guideline for PCI, hybrid revascularization is ideal in patients in whom technical or anatomic limitations to CABG or PCI alone may be present and for whom minimizing the invasiveness (and therefore the risk of morbidity and mortality) of surgical intervention is preferred (38). Patient selection based on the heart team's approach is the key point in whether the HCR strategy could offer favorable outcomes for patients with multivessel disease. The heart team should review the patient's medical condition and coronary anatomy, determine that PCI for non-LAD and grafting LAD with LIMA are both technically feasible and reasonable, and discuss revascularization options with the patient before the HCR strategy is finally selected.

Study limitations. First, this study was based on the retrospective design; thus, patient selection bias might exist. Second, hybrid operating rooms are available only in some large medical centers. Patients for 1-stop HCR were also carefully selected, and its performance required close collaboration of the experienced surgeons and cardiologists, so our results should be interpreted as effects of the heart team approach and therefore used with caution in generalizing

Table 8 MACCE in Hybrid, CABG, and PCI Groups From Low to High SYNTAX Score Tertile

	Hybrid	CABG	PCI	p Value
Low	n = 42	n = 45	n = 55	
Death	0	2	1	0.522
Myocardial infarction	0	1	2	0.554
Neurologic event	0	1	2	0.503
Repeat revascularization	2	1	2	0.740
Any MACCE	2	5	7	0.618
Medium	n = 47	n = 40	n = 46	
Death	1	1	1	1.000
Myocardial infarction	0	0	1	0.437
Neurologic event	1	4	1	0.180
Repeat revascularization	1	1	6	0.073
Any MACCE	3	6	9	0.291
High	n = 52	n = 56	n = 40	
Death	0	1	3	0.086
Myocardial infarction	0	2	3	0.157
Neurologic event	1	4	0	0.133
Repeat revascularization	3	1	10	<0.001
Any MACCE	4	8	16	0.002

Abbreviations as in Tables 1 and 5.

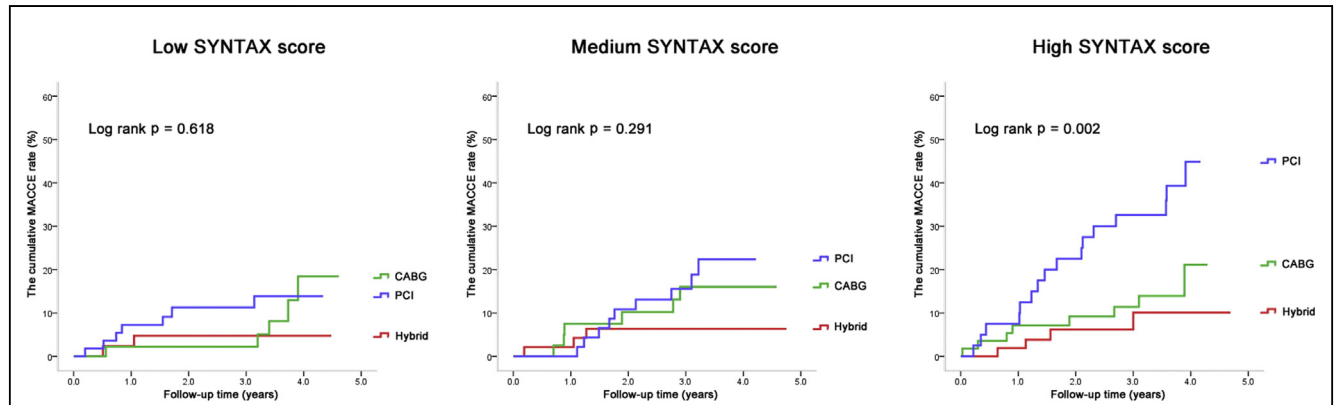


Figure 4 The Cumulative MACCE Rate in Hybrid, CABG, and PCI Groups From Low to High SYNTAX Score Tertile

In the low and medium SYNTAX score tertiles, the MACCE rate in hybrid group was similar to those in the CABG ($p = 0.703$ and $p = 0.254$, respectively) and PCI groups ($p = 0.224$ and $p = 0.114$, respectively). In the high SYNTAX tertile, 1-stop HCR had lower MACCE rate than that with PCI ($p = 0.002$), but similar to that with CABG ($p = 0.362$). Abbreviations as in Figure 1.

these results to a broader population of patients with multivessel coronary artery disease. Third was its relatively small sample size. Long-term follow-up and randomized studies comparing 1-stop HCR with conventional revascularization strategies are warranted.

Conclusions

One-stop HCR provides favorable outcomes for selected patients with multivessel coronary artery diseases in different risk strata. For patients with a high EuroSCORE or

SYNTAX score, it may provide a promising alternative to conventional CABG and PCI. These favorable preliminary findings warrant further investigation of this hybrid procedure.

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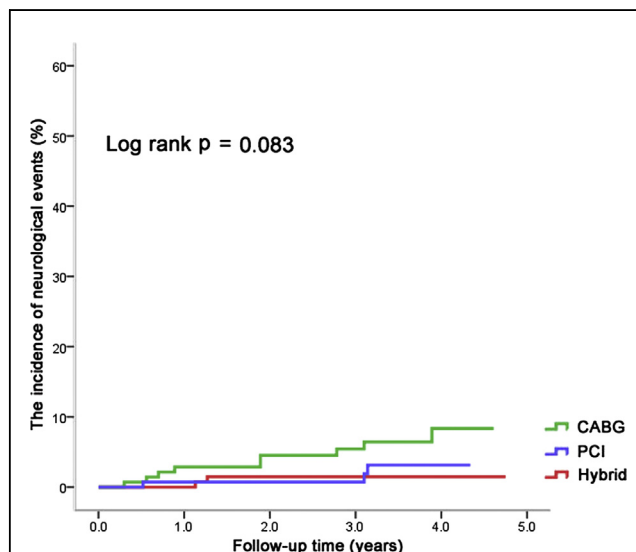


Figure 5 The Incidence of Neurological Events in the Hybrid, CABG, and PCI Groups

The incidence of neurological events in CABG group did not get significant statistical differences with hybrid group during follow-up (0.7% vs. 2.8%; $p = 0.056$). Abbreviations as in Figure 1.

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Key Words: coronary artery bypass graft ■ EuroSCORE ■ hybrid coronary revascularization ■ percutaneous coronary intervention ■ SYNTAX score.